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Validating predictive factors for resting energy expenditure of adolescents in Indonesia

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Abstract

Our objectives were to (1) compare the measured and predicted resting energy expenditure (REE) using 18 equations in normal-weight and obese adolescents, and (2) examine potential predictive factors for accurately estimating REE in obese adolescents. The subjects chosen were 41 obese and 35 normal-weight adolescents living in an urban area in Indonesia. REE was measured using indirect calorimetry and compared with predicted REE determined via 18 equations. New predictive equations were developed via stepwise multiple regression analysis. Mean differences between the predicted and measured REE were within ±5% with 13 equations tested in normal-weight subjects, and only six equations in obese subjects. New predicted REE derived from our new equations was significantly correlated with measured REE ($P < 0.0001$, $R^2 = 0.5$–0.7). Measured REE was overestimated by existing predictive equations, especially in obese subjects. New predictive equations need to be developed that take age, climate and ethnicity into account, in addition to physical characteristics.

Keywords: *resting energy expenditure, obesity, adolescents, Indonesia, predictive equation*

Introduction

Recently, childhood obesity has increased not only in developed countries but also in developing countries. As obese children, especially adolescents tend to stay obese adults, childhood obesity is considered to be a serious problem (Serdula et al. 1993; Molnar and Livingstone 2000).

Although multiple factors contribute to the development of obesity, one main factor is an excess of energy intake to energy expenditure (EE). The largest component of total EE is considered to be basal metabolic rate (BMR; FAO/WHO/UNU 1985). Therefore, accurately estimating BMR to precisely determine energy requirements could help prevent the rise of overweight condition and obesity among young children.

BMR is the minimum EE required to support life, and it is measured under strict conditions. Compared to BMR, resting EE (REE) can be measured under less strict conditions. REE is generally measured using indirect calorimetry, however because of both cost and time, predictive equations have also been utilized.

To estimate both BMR and REE, the FAO (FAO/WHO/UNU 1985), the Schofield (1985), and the Harris and Benedict (1919) equations have been widely used (Müller et al. 2004). However, Henry and Rees (1991) pointed out that these equations are derived from a high proportion of Caucasian individuals, and thereby these equations typically overestimate the REE of tropical people. Furthermore, with the rise of childhood obesity, some predictive equations have been proposed based on a mixed population of obese and non-obese children (Molnar et al. 1995; Müller et al. 2004) and only obese children

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(Tverskaya et al. 1998; Lazzer et al. 2006). However, there is no consensus with respect to which predictive equation is more appropriate for REE estimation in obese children (Hofsteenge et al. 2010).

While Indonesia has seen remarkable improvements in their economic development, childhood obesity has also risen (Popkin et al. 2006). The objectives of this study were to (1) compare the measured REE using calorimetry and predicted REE using 18 predictive equations in normal-weight and obese adolescents in an urban area in Indonesia, and (2) examine the predictive factors for REE estimation in obese adolescents.

Materials and methods

Subjects

The subjects were 76 junior high-school students (age: 12.8 ± 0.4) from Semarang, the capital city of Central Java Province, Indonesia. Their school is located in the central part of the city. Exclusion criteria included a history of metabolic or endocrine diseases and taking medications regularly. There were no exclusion and all 76 subjects completed all measurements. We considered individuals of 10–19 years as 'adolescents' (WHO 1986, 1995). The subjects were divided into two groups: 'normal weight' ($n = 35$) and 'obese' ($n = 41$), based on the body mass index (BMI) cut-off values developed by the International Obesity Task Force (Cole et al. 2000). They were fully informed about the procedures and purpose of this study and informed consent was obtained from each subject. This study was approved by the Ethics Committee of Faculty of Medicine, Diponegoro University, Dr. Kariadi Hospital, Indonesia.

Anthropometry

Anthropometric dimensions were measured following a standard protocol (Weiner and Lourie 1981). Height was measured to the nearest 1 mm using a wall-mounted stadiometer (Seca 213; Seca Ltd, Humburg, Germany). Body weight was measured to the nearest 0.1 kg concurrently with body fat percentage, which was assessed via bioelectric impedance with a body fat analyzer (TBF310; Tanita, Tokyo, Japan). Given that the subjects were wearing a school gym uniform without shoes, we subtracted 0.5 kg from the body weight measurement considering the weight of the clothes. Fat mass (FM) and fat-free mass (FFM) were calculated from these values. Waist and hip circumferences were measured to the nearest 1 mm using a flexible tape measure. BMI (kg/m^2) was calculated using the body weight and height measurements.

Resting energy expenditure

REE was measured in the supine position using an open-circuit indirect calorimetry with the Douglas bag technique (Douglas 1911; Yamauchi and Ohtsuka 2000). Measurements were taken between 06:30 and 09:00 after an overnight fast. After achieving steady state, expired air was collected for 10 min with a Hans Rudolph mask. A portable gas monitor (AR-1, Arco System, Chiba, Japan) was used to determine the O_2 and CO_2 content and the volume of the expired air. The energy values were automatically calculated using the Weir equation (Weir 1949).

Predictive equations for BMR

Eighteen BMR predictive equations were used in this study to compare the measured and predicted REE. Table I shows the 18 predictive equations for REE. Among them, the FAO 1985-W (weight), the FAO 1985-WH (weight and height; FAO/WHO/UNU 1985), the FAO 2004 (FAO/WHO/UNU 2004), the Harris and Benedict (1919), the Schofield-W and the Schofield-WH (Schofield 1985) equations were based on normal-weight subjects. The Molnar 1 and 2 (Molnar et al. 1995), as well as the Müller 1 and 2 (Müller et al. 2004), equations were based on a mixed population of normal-weight and obese children. Tverskaya et al. (1998) and the Lazzer 1 and 2 equations (Lazzer et al. 2006) were based on only obese children. The Japan-DRI (Ministry of Health, Labour and Welfare 2010), and the Henry and Rees 1991-W and Henry and Rees 1991-WH (Henry and Rees 1991) equations were specific to Japanese and tropical populations, respectively. In the Henry 2005-W and the Henry 2005-WH equations, tropical people accounted for roughly 38% of all subjects (Henry 2005).

The predicted REE was determined using the following equation: $REE = 1.2 \times BMR$ (FAO/WHO/UNU 2004).

Statistical analysis

Data were presented as mean ± SD. Differences between normal-weight and obese subjects in the

Table I. Predictive equations for REE.

REE predictive equation	Age range (years)
FAO 1985-W	10–18
FAO 1985-WH	10–18
FAO 2004	10–18
Harris–Benedict	20–70
Schofield-W	10–18
Schofield-WH	10–18
Molnar 1	10–16
Molnar 2	10–16
Müller 1	5–17
Müller 2	5–17
Tverskaya	6–18
Lazzer 1	7–18
Lazzer 2	7–18
Japan-DRI	12–14
Henry and Rees 1991-W	10–18
Henry and Rees 1991-WH	10–18
Henry 2005-W	10–18
Henry 2005-WH	10–18

measured physical characteristics were determined via a Student *t*-test. The paired *t*-test was used to calculate the differences between measured and predicted REE. The percentage of subjects that had a measured REE within ±10% of the predicted REE was calculated (Hofsteenge et al. 2010). We defined that a measured REE between 90 and 110% of the predicted REE was an accurate prediction, whereas a measured REE < 90% of the predicted REE was considered to be an underestimation and a measured REE > 110% of the predicted REE was considered to be an overestimation. Relative difference (%; Molnar et al. 1995) was calculated. Additionally, the Bland–Altman method was used to compare the measured and predicted REE (Bland and Altman 1986). In the Bland–Altman comparison, the magnitude bias (error correlation coefficients) between the difference (measured REE − predicted REE) and the mean of measured and predicted REE was ascertained (McDuffie et al. 2004).

Stepwise multiple regression analysis (forward selection technique) was used with actual measured REE (kcal/d) as the dependent variable and height (cm), weight (kg), age (years), sex (boys = 0, girls = 1), FM (kg) and FFM (kg) as independent variables. Pearson's correlation and paired *t*-test analyses were performed to test the relationship between measured and predicted REE. Statistical analysis was performed with the JMP 8.0.2 software package (SAS Institute, Cary, NC, USA) and a *P* value of < 0.05 was considered significant.

Results

Anthropometry

Table II shows the physical characteristics of the subjects. There were no significant differences in age and height between the normal-weight and obese subjects in both sexes. However, obese subjects were significantly heavier and had higher BMI than normal-weight subjects ($P < 0.0001$). Percent body fat was markedly different between two groups, especially in males. Obese males had twice the body fat (%) than normal-weight males ($P < 0.0001$). Measured REE was over 250 kcal/d higher in obese than in normal-weight subjects ($P < 0.05$ for males and $P < 0.005$ for females).

Comparison of measured versus predicted REE

Tables III and IV show the comparison between measured and predicted REE in 41 obese subjects and 35 normal-weight subjects, respectively. In obese subjects, there were no significant differences in the means and magnitude bias, as determined by the Bland–Altman plot, between the measured and predicted REE with the Schofield-W and Henry and Rees 1991-WH equations (Table III). Additionally, accuracy predictions (%) were higher with the Molnar 1 and 2, as well as with the Müller 1 equations. Furthermore, REE in over 90% subjects was overestimated with the Japan-DRI equation. In normal-weight subjects, there were no significant differences in the means and magnitude bias, as determined via the Bland–Altman plot, between measured and predicted REE with the Lazzer 1 and 2, as well as with the Japan-DRI equations (Table IV). Thirteen out of 18 predictive equations had high accuracy (over 60%).

Figure 1 shows the relative differences (%) between measured and predicted REE. The Harris–Benedict, the Molnar 1, the Müller 1, and the Henry and Rees 1991-WH equations had the smallest relative differences between measured and predicted REE in the entire subject pool. The Harris–Benedict, the Molnar 1 and 2, and the Müller 1 equations had the smallest relative differences between measured and predicted REE in obese subjects. The Harris–Benedict, the Lazzer 1 and 2, the Henry and Rees (1991), and the Henry (2005) equations had the smallest relative difference between measured and predicted REE in normal-weight subjects. With the Japan-DRI equation, there was a relative difference of −3.0% and −29.3% in normal-weight and obese subjects, respectively.

New predictive equations for REE

Table V shows the new predictive equations for REE developed from a stepwise multiple regression

Table II. Characteristics of subjects (mean ± SD).

	Boys			Girls		
	Normal ($n = 15$)	Obesity ($n = 30$)	*P*	Normal ($n = 20$)	Obesity ($n = 11$)	*P*
Age (years)	12.9 ± 0.4	12.8 ± 0.3	n.s	12.8 ± 0.4	12.6 ± 0.5	n.s
Height (cm)	157.1 ± 7.6	154.8 ± 6.5	n.s	152.2 ± 5.4	152.4 ± 6.7	n.s
Weight (kg)	45.7 ± 6.3	66.9 ± 8.8	< 0.0001	44.4 ± 5.1	68.1 ± 10.4	< 0.0001
BMI (kg/m^2)	18.4 ± 1.4	27.9 ± 3.1	< 0.0001	19.1 ± 1.5	29.2 ± 2.8	< 0.0001
Body fat (%)	16.7 ± 4.6	32.6 ± 10.4	< 0.0001	22.5 ± 3.8	38.3 ± 4.2	< 0.0001
FFM (kg)	37.9 ± 4.8	44.8 ± 7.3	< 0.005	34.3 ± 2.8	41.8 ± 5.5	< 0.0001
Waist (cm)	69.4 ± 5.7	91.5 ± 8.4	< 0.0001	65.8 ± 8.1	82.1 ± 6.3	< 0.0001
Hip (cm)	85.3 ± 4.9	101.3 ± 5.2	< 0.0001	87.5 ± 4.6	103.4 ± 7.0	< 0.0001
Measured REE (kcal/d)	1701 ± 279	1964 ± 314	< 0.05	1517 ± 175	1834 ± 302	< 0.005

Table III. Evaluation of REE predictive equations in obese subjects ($n = 41$).

REE predictive equation	REE (kcal/d)	Mean difference (kcal/d)†	Magnitude bias‡	Accurate predictions (%)¶	Under predictions (%)§	Over predictions (%)‖
REE measured	1929 ± 316					
FAO 1985-W	2108 ± 219	−178.5**	0.35*	41.5	7.3	51.2
FAO 1985-WH	2168 ± 188	−239.1**	0.51**	29.3	4.9	65.9
FAO 2004	2134 ± 221	−204.5**	0.34*	41.5	4.9	53.7
Harris–Benedict	1963 ± 177	−33.3	0.58**	51.2	12.2	36.6
Schofield-W	1996 ± 221	−67.0	0.28	46.3	19.5	34.1
Schofield-WH	2070 ± 245	−140.7**	0.21	46.3	7.3	46.3
Molnar 1	1887 ± 175	39.8	0.61**	65.9	22.0	12.2
Molnar 2	1877 ± 182	50.0	0.58**	68.3	22.0	9.8
Müller 1	1855 ± 138	71.4	0.77**	65.9	24.4	9.8
Müller 2	1977 ± 163	−51.0	0.66**	53.7	12.2	34.1
Tverskaya	2028 ± 238	−98.7*	0.26	53.7	12.2	34.1
Lazzer 1	2052 ± 197	−125.4**	0.48**	46.3	7.3	46.3
Lazzer 2	2070 ± 192	−143.7**	0.51**	43.9	7.3	48.8
Japan-DRI	2471 ± 340	−541.6**	−0.21	7.3	0.0	92.7
Henry and Rees 1991-W	2098 ± 281	−171.3**	0.14	41.5	9.8	48.8
Henry and Rees 1991-WH	1999 ± 248	−72.8	0.29	46.3	14.6	39.0
Henry 2005-W	2080 ± 239	−150.6**	0.33*	41.5	9.8	48.8
Henry 2005-WH	2018 ± 221	−88.6*	0.42**	48.8	9.8	41.5

*$P < 0.05$, **$P < 0.01$; †measured REE − predicted REE; ‡the Bland and Altman bias (error correlation) coefficients; ¶the percentage of subjects with measured REE within ±10% of the predicted REE; §the percentage of subjects with measured REE within <−10% of the predicted REE; ‖the percentage of subjects wtih measured REE within >+10% of the predicted REE.

analysis. All new predicted REE derived from new equations significantly correlated with measured REE ($P < 0.0001$, $R^2 = 0.5$–0.7). There were no significant differences between the measured and new predicted REE with all the new equations. Relative differences ranged from −1.7 to +0.8%. A Bland–Altman analysis between the measured and predicted REE demonstrated that almost all the points (91–95%) fell within ±2 SD (data not shown).

Discussion

Factors responsible for the overestimation of REE

In this study, measured REE was generally overestimated with existing predictive equations in young adolescent Indonesian subjects. There are two potential factors for this finding. One factor is that climate may influence the REE. Henry and Rees (1991) reported that tropical populations have lower BMR compared with temperate populations.

Table IV. Evaluation of REE predictive equations in normal-weight subjects ($n = 35$).

REE predictive equation	REE (kcal/d)	Mean difference (kcal/d)†	Magnitude bias‡	Accurate predictions (%)¶	Under predictions (%)§	Over predictions (%)‖
REE measured	1596 ± 243					
FAO 1985-W	1629 ± 141	−33.4	0.52**	62.9	11.4	25.7
FAO 1985-WH	1725 ± 118	−128.9**	0.66**	42.9	8.6	48.6
FAO 2004	1637 ± 151	−40.8	0.45**	65.7	11.4	22.9
Harris–Benedict	1609 ± 120	−12.8	0.67**	65.7	8.6	25.7
Schofield-W	1662 ± 134	−66.5	0.46**	40.0	17.1	42.9
Schofield-WH	1635 ± 155	−39.3	0.41*	65.7	11.4	22.9
Molnar 1	1511 ± 155	82.1*	0.40*	68.6	20.0	11.4
Molnar 2	1504 ± 164	90.0**	0.34*	62.9	25.7	11.4
Müller 1	1660 ± 134	−66.7*	0.55**	62.9	8.6	28.6
Müller 2	1679 ± 124	−85.7**	0.64**	54.3	8.6	37.1
Tverskaya	1659 ± 167	−63.7*	0.34*	57.1	8.6	34.3
Lazzer 1	1619 ± 187	−25.9	0.17	62.9	11.4	25.7
Lazzer 2	1603 ± 175	−9.9	0.24	65.7	14.3	20.0
Japan-DRI	1630 ± 214	−34.3	0.0048	57.1	11.4	34.3
Henry and Rees 1991-W	1558 ± 172	36	0.43**	65.7	20.0	14.3
Henry and Rees 1991-WH	1567 ± 175	26.8	0.41*	65.7	20.0	14.3
Henry 2005-W	1591 ± 144	4.8	0.60**	71.4	11.4	17.1
Henry 2005-WH	1598 ± 146	−2.4	0.59**	71.4	11.4	17.1

*$P < 0.05$, **$P < 0.01$; †measured REE − predicted REE; ‡the Bland and Altman bias (error correlation) coefficients; ¶the percentage of subjects with measured REE within ±10% of the predicted REE; §the percentage of subjects with measured REE within <−10% of the predicted REE; ‖the percentage of subjects with measured REE within >+10% of the predicted REE.

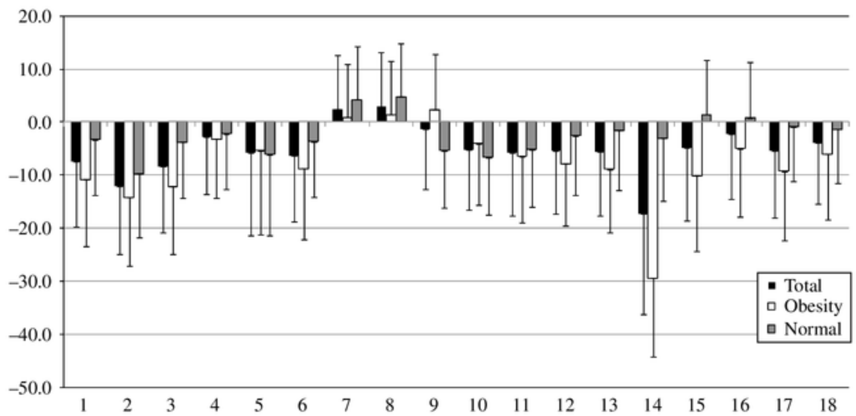

Figure 1. Relative differences* (%) between measured REE and predicted REE determined via predictive equations in total ($n = 76$), obese ($n = 41$), normal-weight ($n = 35$) subjects. Each number denotes the following predictive equation: 1, FAO 1985-W; 2, FAO 1985-WH; 3, FAO 2004; 4, Harris-Benedict; 5, Schofield-W; 6, Schofield-WH; 7, Molnar 1; 8, Molnar 2; 9, Müller 1; 10, Müller 2; 11, Tverskaya; 12, Lazzer 1; 13, Lazzer 2; 14, Japan-DRI; 15, Henry and Rees 1991-W; 16, Henry and Rees 1991-WH; 17, Henry 2005-W; and 18, Henry 2005-WH. *Measured REE–predicted REE/(measured REE × 100).

In a study with Malaysian adults, it was found that their BMR was 9–13% overestimated with the FAO 1985 equation, and only 2–6% overestimated with the Henry and Rees (1991) equation (Ismail et al. 1998). Similarly, in a study with Malaysian adolescents, the difference between measured and predicted REE with the Henry and Rees (1991) equation tended to be smaller than that obtained with the FAO 1985 equation (Poh et al. 1999). Ismail et al. (1998) pointed out that Malaysians naturally have the capacity to slow down metabolism so as to adapt to the hot and humid climate throughout the year. Given that Indonesia is geographically close to Malaysia, and that both countries have similar climate patterns, then the subjects of this study could also have a similar capacity to decrease metabolism. Additionally, Froehle (2008) pointed out that both the mean annual temperature and the highest heat index temperature are related to BMR, and that BMR increases approximately by 4–5 kcal/d for every 1°C decrease in mean annual temperature. Therefore, it is possible that climate is related to REE and may play a crucial role in estimating REE.

The second factor that may influence REE is ethnicity. Case et al. (1997) reported that the measured REE of Asian women living in the USA was overestimated by both the FAO 1985 and the Harris–Benedict equations. Specifically, they recruited subjects who had been in the USA for at least 9 months prior to REE measurements. Therefore, the REE of Asian women could be lower than that of Caucasian independent of the climate. Wouters-Adriaens and Westerterp (2008) noted that REE differences between Caucasians and Asians, where 40% of Asians were from Indonesia, were due to differences in total FFM. Deurenberg et al. (2002) have pointed out that the relationship between BMI and body fat (%) varies among ethnic groups. In a study with Indonesian and Dutch Caucasian subjects, it was found that Indonesians had a 4.8% higher body fat than Dutch Caucasians when controlled for age, gender, height and weight (Gurrici et al. 1998). Thus, it is possible that the overestimation of the subject's REE using Caucasian-based predictive equations might be attributed to a genetically high body fat percentage of the subjects.

Moreover, Gurrici et al. (1999) reported that Malay Indonesians have a 1.7 kg/m^2 lower BMI than Chinese Indonesians after correcting for differences in age, sex and body fat percentage. Thus, based on these findings, we hypothesized that the relative differences in FFM between these ethnic groups may contribute

Table V. New predictive equations for the calculation of REE.

	New equation for REE (kcal/d)	R^2	Mean difference (kcal/d)†	Relative difference (%)‡
Total Eq	REE = 40.2 Sex* + 11.2 weight (kg) + 9.6 height (cm) + 10.3 FFM (kg) − 767.0	0.65*	−7.1	−1.7
Obesity Eq	REE = 23.7 weight (kg) + 11.3 height(cm) − 10.7 FM (kg) − 1162.3	0.55*	4.8	−0.8
Normal-weight Eq	REE = 40.4 FFM (kg) + 146.4	0.48*	0.11	−1.0

Sex: boys = 0, girls = 1; *Significantly correlated with measured REE. $P < 0.0001$; †Measured REE − predicted REE; ‡Measured REE − Predicted REE/Measured REE) × 100 to differences in their REE. In this study, of the 76 subjects, 46% were Malay Indonesians and 54% were Chinese Indonesians. Interestingly, there were no significant differences in BMI, body fat percentage, FM, FFM and REE between these two ethnic groups. Additionally, a separate comparison of obese and normal-weight individuals revealed that there were no significant differences between these two ethnic groups. Therefore, in this study, there were no differences in REE between Malay Indonesians and Chinese Indonesians, as there were no significant differences in both body size and body composition between these groups. Although previous studies in adult populations found a relationship between REE and ethnicity (Hofsteenge et al. 2010), this study did not find such a relationship in children. However, since ethnic differences in body composition are inherent (Wouters-Adriaens and Westerterp 2008), then REE that is associated with body composition might be genetically different among different ethnic groups. Thus, there are limitations with regard to applying predictive equation based on Caucasian populations to Asian populations, as body composition might be different among each ethnic group, even among Asian populations. These findings indicate that new predictive equations should be developed with respect to the physical characteristics of each ethnic population.

Validation of the predictive factors in REE estimation among obese adolescents

In this study, 13 out of 18 predictive equations in the normal-weight group had mean differences that were within ±5% from measured REE. Only six equations had mean differences within the same range in the obese group. Also, 13 predictive equations in the normal-weight group had high accuracy (over 60%), whereas there were only three equations with the same accuracy in the obese group. These results suggest that the REE of obese adolescents tends to be overestimated by existing predictive equations. In REE estimation of obese subjects, using the Molnar 1 and 2 and the Müller 1 equations, we found that the relative difference was small (+0.9 to +2.3%) and subject's REE was accurately estimated. Corroborating our findings, a study on Dutch obese adolescents reported that the Molnar equation was the most appropriate for REE estimation in obese adolescents (Hofsteenge et al. 2010). Conversely, the Schofield-WH or the FAO 1985-WH equations were reported as most appropriate for REE estimation in obese adolescents (Dietz et al. 1991; Rodriguez et al. 2000). Therefore, which predictive equation is most appropriate for REE estimation in obese adolescents is not known.

In this study, there was a small relative difference in normal-weight subjects when predictive equations based only on weight were used (i.e. FAO 1985-W, FAO 2004, Japan-DRI, Henry and Rees 1991-W, Henry 2005-W). However, in obese subjects, measured REE was overestimated by 9–29% with these equations. These data suggest that variables other than weight are needed for accurate REE estimation in obese adolescents. Both FM and FFM increase as weight increases; however, adipose tissue expands faster than lean tissue (Horgan and Stubbs 2003). Thus, relative FFM of obese adolescents could be lower than that of normal-weight adolescents. A previous study found that FFM was necessary for proper REE estimation in obese adolescents (Dietz et al. 1991; Molnar and Schutz 1997). Conversely, it has been reported that the difference between measured and predicted REE did not improve even when an FFM-based equation was used (Hofsteenge et al. 2010).

Hofsteenge et al. (2010) noted that height was an important variable for REE estimation in obese adolescents. A study on Brazilian obese adolescents found that there were no significant differences between measured and predicted REE only when the Harris–Benedict equation was used, and suggested that this result was due to the inclusion of both height and age (Schneider and Meyer 2005). Similarly, in this study, the difference between measured and predicted REE was small when we used the Harris–Benedict equation in both obese and normal-weight subjects.

Additionally, as with the Harris–Benedict equation, both the Molnar 1 and 2, and the Müller 1 equations, which include height, weight and age, accurately estimated the REE of obese subjects. The Müller 2, Tverskaya and Lazzer 2 equations all include body composition variables (i.e. FM, FFM), however, none of them include height. Thus, inclusion of height for REE estimation in obese adolescents is necessary. Furthermore, age appears to be an important variable for REE estimation, as well. Of the 18 predictive equations used in this study, equations that include age are: the Harris–Benedict, the Molnar 1 and 2, the Müller 1, the Tverskaya and the Lazzer 1 and 2 equations. The other equations are similarly applied in a particular age range group. For example, when we use the FAO 1985, the FAO 2004, the Schofield, the Henry and Rees and Henry (2005) equations, the REE of adolescents aged 10–18 years are estimated by the same equations. Similarly, the Müller 2 and the Japan-DRI equation are used commonly in those aged 5–17 and 12–14 years, respectively. However, secondary sexual characteristics are developed during these age ranges, and thus body size and body composition change rapidly, which may influence the REE of adolescents. Henry (2005) pointed out that it is necessary that REE estimation among those aged 10–18 years be assessed according to the different stages of pubertal development and in narrow age ranges. Therefore, especially in obese adolescents, REE estimation should be conducted in more detail including both age and height, as well as variables of body composition. One of the limitations of this study was the small number of subjects and they are not representative of Indonesian adolescents. Also, subjects of this study were narrow age range (11–13 years). Consequently, the new predictive equations did not include the entire age spectrum of adolescence and thereby can only be applied to a limited age range. Further research is needed to develop the new predictive equations in larger scale sample and wider range of age.

Conclusions

In this study, the measured REE of Indonesian adolescents was overestimated with existing predictive equations. This observation may be attributed to the climate and ethnic factors. Additionally, since REE of obese adolescents is more likely to be overestimated, new predictive equations should be developed that are more specific to the subjects by taking age, body size, body composition, climate, ethnicity and other factors into account. A better understanding of these variables may prevent further rises in overweight condition and obesity in children and adolescents.

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Notes

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